ENVIRONMENTAL BENEFITS OF A MEGASOLAR CDTE PV PROJECT IN JAPAN

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ABSTRACT

Displacing grid electricity with PV in Japan can provide a wide variety of benefits to ecosystems, human health, and natural resources, and thin-film CdTe has among the lowest life cycle impacts of major PV technologies. Use of high-value PV recycling and responsible land use practices can further improve the environmental profile of PV. The safety of CdTe PV has been evaluated in Japan by NEDO, MOE/METI, and researchers at the University of Tokyo and Yokohama National University. CdTe PV converts mining byproducts into a leading eco-efficient PV technology that supports Japan's energy transition.

1. INTRODUCTION

Following the 2011 Tohoku earthquake and tsunami and subsequent nuclear accidents, Japan has undertaken an energy transition in which alternatives to nuclear power such as coal, LNG, oil, and renewables have been increasingly utilized. With the exception of renewables, these energy sources are largely imported, with associated impacts on energy cost and security. Because of the energy transition and solar as a domestic energy resource, Japan is a strong candidate for a sustainable PV market. Japan has further incentivized the adoption of solar PV using a feed-in-tariff scheme for both small and large-scale (10 kW or more) PV projects. In this study, the environmental benefits from displacing Japanese grid electricity with a large-scale (1.3MWdc) CdTe rooftop and ground-mount PV system at Kitakyushu-shi in Japan (Fig. 1) and from rooftop mono and multi-crystalline silicon (mono-c-Si and multi-c-Si) and CIGS PV systems are evaluated.

Fig. 1 1.3MWdc CdTe PV system at Kitakyushu-shi in Japan

2. METHODS

Life cycle assessment (LCA) has been conducted with Simapro (V. 8.0.3) software, Ecoinvent (V. 2.2) unit processes, and International Reference Life Cycle Data System (ILCD) impact assessment methods (2011 Midpoint Method V. 1.04). Life cycle inventory (LCI) data collection for PV systems follow the methodology in Sinha et al. [1] with the addition of CIGS data from de Wild-Scholten [2], balance of systems (BOS) recycling data based on Bergesen et al. [3], and Japanese grid electricity data from Itten et al. [4].

The assessment is based on 2012 module conversion efficiencies of 15.1%, 14.7%, 12.7%, and 12.0% from Photon International, and degradation rates of 0.36%, 0.64%, 0.40%, and 0.96% per year [5] for mono-c-Si, multi-c-Si, CdTe, and CIGS, respectively. Performance ratios of 0.75 for rooftop systems and 0.80 for ground-mount systems and 30 year project lifetimes are assumed. Plane-of-array irradiation is 1419 kWh/m^2/yr at Kitakyushu-shi (MONSOLA-11 database).

3. RESULTS AND DISCUSSION

Ground-mount CdTe PV and roof-mount c-Si, CdTe, and CIGS PV systems provide over 50% reductions in environmental impacts for a wide variety of damage categories, including ecosystems, human health, and natural resources (Table 1). CdTe systems have among the lowest impacts of PV technologies (Fig. 2), and also the lowest life cycle Cd emissions (Fig. 3). The carbon footprint of the CdTe PV system is 20-22 g CO2-eq/kWh.

Table I. ILCD environmental impacts relative to Japanese grid electricity (module+BOS without recycling; green: <50%; yellow: <100%; red: ≥100%)

		Mono-Si PV	Multi-Si PV	CIGS	CdTe PV (ground)	CdTe PV (roof)	Range
Ecosystems	Climate change	🟢	🟢	🟢	🟢	🟢	3% - 13%
	Terrestrial eutrophication	🟢	🟢	🟢	🟢	🟢	5% - 19%
	Freshwater eutrophication	🟢	🟢	🟢	🟢	🟢	8% - 16%
	Marine eutrophication	🟢	🟢	🟢	🟢	🟢	5% - 21%
	Acidification	🟢	🟢	🟢	🟢	🟢	4% - 21%
	Photochemical ozone formation	🟢	🟢	🟢	🟢	🟢	5% - 19%
	Ozone depletion	🟢	🟢	🟢	🟢	🟢	7% - 14%
	Ionizing radiation E (interim)	🟢	🟢	🟢	🟢	🟢	1% - 4%
	Freshwater ecotoxicity	🟢	🟢	🟢	🟢	🟢	28% - 42%
Human Health	Human toxicity, cancer effects	🟢	🟢	🟢	🟢	🟢	11% - 27%
	Human toxicity, non-cancer effects	🟢	🟢	🟢	🟢	🟢	29% - 48%
	Ionizing radiation HH	🟢	🟢	🟢	🟢	🟢	1% - 5%
	Particulate matter	🟢	🟢	🟢	🟢	🟢	5% - 47%
Natural Resources	Water resource depletion	🟢	🟢	🟢	🟢	🟢	2% - 17%
	Land use	🟢	🟢	🟢	🟢	🟢	5% - 36%
	Mineral, fossil & renewable resource depletion	🔴	🔴	🔴	🔴	🔴	>100%

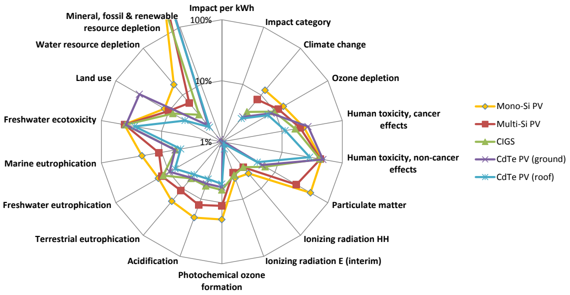

Fig. 2 ILCD environmental impacts of PV relative to Japanese grid electricity (module+BOS without recycling)

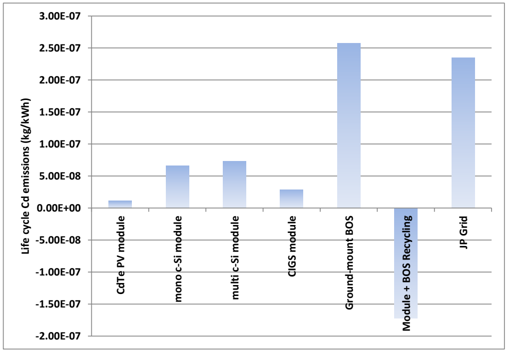

Fig. 3 Life cycle Cd emissions from PV and grid electricity in Japan

The only ILCD damage category where PV does not provide a comparative benefit is with respect to mineral, fossil, and renewable resource depletion. While solar resources are abundant, the materials used to manufacture and deploy PV systems (e.g., In, Ag, Cd, Te, Cu, Al, Zn) are finite. The impacts of resource depletion by PV modules may be mitigated by high-value end-of-life module and BOS recycling that recovers both bulk materials (glass, aluminum, copper, steel) and semiconductor and rare materials for reuse in new products. For example, CdTe PV recycling technologies currently provide approximately 90% recovery of glass and up to 95% recovery of semiconductor material [1]. Ground-mount PV has greater land use impacts than roof-mount PV (Fig. 2), though these impacts are minimized by use of industrial land in Kitakyushu-shi. Best practices for PV land use have been outlined by the World Wildlife Fund [6].

In addition to life cycle assessment, risk assessment has been conducted by NEDO, MOE/METI, and researchers at the University of Tokyo and Yokohama National University in Japan to evaluate CdTe PV safety in the case of fire and breakage [7], flooding [8], end-of-life disposal [9], and over the entire life cycle [10]. Cd is a by-product of Zn production needed for steel products, and substantial quantities are produced regardless of its use in PV. With the potential for a Cd oversupply problem in Japan in the near future [11], a sustainable use of Cd is needed. CdTe PV converts mining byproducts into a leading eco-efficient PV technology that supports Japan’s energy transition (Fig. 4).

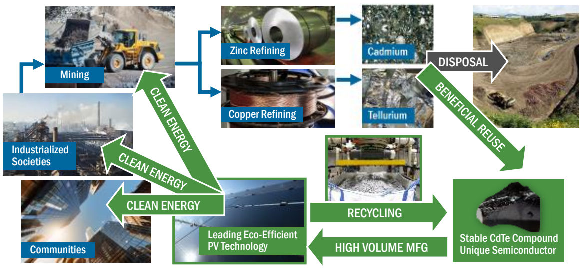

Fig. 4 Mineral resource life cycle of Cd in CdTe PV.

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